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A COMPARATIVE STUDY ON IMAGE FILTERS FOR NOISE REDUCTION IN LUNG CT SCAN IMAGES

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ABSTRACT

The main aim of image enhancement technique is to improve the quality of an image for early diagnosis. Enhanced medical images are desired by a surgeon to help diagnosis and interpretation because medical image qualities are often deteriorated by artifacts and noise. Our targets of medical image enhancement are mainly to solve problems of the high level noise of a medical image. Noise filtering techniques that maintain image contrast while decreasing image noise have the potential to optimize the quality of computed tomography (CT) images acquired at reduced radiation dose. In this paper we compare the various linear and non-linear filters on lung CT scan images for removing the noises and express the results in terms of evaluation metrics such as PSNR, MAE and etc.

KEYWORDS: Lung CT Scan Images, Noise Reduction, Linear Filters, Non-Linear Filters, Image Quality Measures

INTRODUCTION

Medical imaging is the technique and process used to create images of the human body for clinical purposes and diagnosis. The x-ray computed tomographic (CT) scanner has made it possible to detect the presence of lesions of very low contrast. The noise in the reconstructed CT images is significantly reduced through the use of efficient x-ray detectors and electronic processing. CT basically uses x-rays to obtain structural and functional information about the human body. In CT, the image quality is influenced by many technical parameters. One of the most important parameter is the radiation dose. The quality of image increases with the significant amount of radiation dose [1]. But an increased amount of x-rays being absorbed by the human body increases the chances of cancer. So we need to reduce the radiation dose which is responsible for image noise in CT. So for proper analysis and diagnosis, it is required to reduce the image noise. The CT reconstruction technique almost completely eliminates the superposition of anatomic structures, leading to a reduction of structural noise. The random noise in a CT image that ultimately limits the ability of the radiologist to discriminate between two regions of different density. Because of its unpredictable nature, such noise cannot be completely eliminated from the image and will always lead to some uncertainty in the interpretation of the image. The noise present in the images may appear as additive or multiplicative components and the main purpose of noise removal is to remove these noisy components while preserving the important signal as much as possible. Noise removal therefore plays a vital role in medical imaging applications in order to enhance and recover the analysis details that may be hidden in the data. For this purpose filtering is thus applied to clear such images. Any noise reduction algorithm aims to enhance the fidelity of an image which actually means removing the random and uncorrelated structures and retaining the resolution.

There are several types of image "noise" that can interfere with the interpretation of an image. Noise may infiltrate and corrupt the data at any point in the CT process, the ultimate source of noise is the random, statistical noise, arising

from the detection of a finite number of x-ray quanta in the projection measurements. Image mottling, or fluctuations in the image density that change from one image to the next in an unpredictable and random manner, may be termed as random noise. Statistical noise in x-ray images arises from the fluctuations inherent in the detection of a finite number of x-ray quanta. Statistical noise may also be called quantum noise. In processing electric signals, electronic circuits inevitably add some noise to the signals called Electronic noise. The wide variety of artifacts that can be produced by CT scanners, artifacts might be viewed as a form of noise in that they interfere with the interpretation of the CT image is called artifact noise. Density variations in the object being imaged that interfere with the diagnosis are sometimes referred to as structural noise or structural clutter. In standard radiography a large amount of structural clutter is produced by the superposition of various anatomic structures.

Image filtering is mainly used to remove the noise that is present and retains the significant information, regardless of the frequency contents of the signal. It is entirely different content and retains low frequency content. Filtering has to be performed to recover the useful information. In this process much attention is kept on, how well the edges are preserved and how much of the noise granularity has been removed [4-5] the main purpose of an image filtering algorithm is to eliminate the unwanted noises while preserving the important features of an image. In this paper we focusing on linear filters such as mean filter and wiener filter and nonlinear filters such as median filter and entropy filter for noise removal in lung CT scan images.

LINEAR FILTERS

Linear filtering is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighborhood. In linear filters the convolution process is used for implementing the neighboring kernels as neighborhood function. The following section describes the linear filters such as mean filter and wiener filters.

Mean Filter: The idea of mean filtering is simply to replace each pixel value in an image with the average value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. Mean filtering is usually thought of as a convolution filter. Like other convolutions it is based around a kernel, which represents the shape and size of the neighborhood to be sampled when calculating the mean [2] [3]. Let S_{xy} represent the set of coordinates in a rectangular sub-image window of size m X n, centered at point(x, y). The arithmetic mean filter filtering process computes the average value of the corrupted image g(x, y) in the area defined by S_{xy}. The value of the restored image *f* at any point (x, y) is simply the arithmetic mean computed using the pixels in the region defined by S_{xy}. In other words,

$$f(x,y)=\frac{1}{mn}\sum_{(s,t)\in S_{xy}} g(s,t)$$

This operation can be implemented using a convolution mask in which all coefficients have value 1/mn. An example of mean filtering of a single 3x3 window of values is shown below.

2	3	4
2	4	3
3	4	2

2+3+4+2+4+3+3+4+2=27/9=3

*	*	*
*	3	*
*	*	*

Mean filter simply smooth local variations in an image. Noise is reduced as a result of blurring.

Wiener Filter: The Wiener filtering executes an optimal tradeoff between inverse filtering and noise smoothing. It removes the additive noise and inverts the blurring simultaneously. Wiener filter estimates the local mean and variance around each pixel [2][3][4].

$$\mu = \frac{1}{NM} \sum_{n1,n2\epsilon\eta} a(n1, n2)$$

And

$$\sigma^2 = \frac{1}{NM} \sum_{n1,n2\epsilon\eta} a^2(n1, n2) - \mu^2$$

Where η is the N-by-M local neighborhood of each pixel in the image, then creates a pixel-wise wiener filter using these estimates,

$$b(n1, n2) = \mu + \frac{\sigma^2 - v^2}{\sigma^2}(a(n1, n2) - \mu)$$

Where $v^2$the noise variance is not given, then the average of all the local estimated variances. Wiener is a frequency domain filter, which removes Gaussian noises from the images.

NON-LINEAR FILTERS

Linear filters may lead to the blurring of edges. To overcome such a problem non-linear filters are used for noise reduction. These filters help to preserve edges. The following section describes the non-linear filters such as median filter and entropy based filters.

Median Filter: Median filter is an example of non-linear filters. In median filter, the ranking of the neighboring pixels is done according to the intensity or brightness level and value of the pixel under evaluation is replaced by the median value of surrounding pixel values[2][3].

$$f(x, y) = median_{(s,t)\epsilon s_{xy}}\{g(s, t)\}$$

The original value of the pixel is included in the computation of the median. An example of median filtering of a single 3x3 window of values is shown below.

5	4	3
3	2	1
6	7	9

1, 2, 3, 3, **4**, 5, 6, 7, 9

*	*	*
*	4	*
*	*	*

Center value (previously 2) is replaced by the median of all nine values (4). Median filters are quite popular because, for certain types of random noise, they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size. Median filters are particularly effective in the presence of both bipolar and unipolar impulse noise.

Entropy Filter: Entropy filters replacing every value by the information entropy of the values in its range of the specified neighborhood. Entropy Filter computes the information entropy of the values in *(2r+1)* X *(2r+1)* blocks centered on each pixel. Given a set of values P_i the information entropy is calculated by

$$-\sum P_i \log(P_i)$$

Entropy filtering can reveal JPEG compression artifacts and reveals the presence of padding in an image.

EVALUATION METRICS

Comparing the reconstruction of an image requires a measure of image quality. In order to evaluate the results in our comparison we uses Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), Mean Absolute Error (MAE), and Image Quality Index[6].

The PSNR is most commonly used as a measure of quality of reconstruction in image compression etc. It is most easily defined via the mean squared error (MSE) which for two $m \times n$ monochrome images I and K where one of the images is considered a noisy approximation of the other is defined as [5]:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} ||I(i,j) - K(i,j)||^2$$

The PSNR is defined as:

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

Here, MAX_I is the maximum pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255.

Root-Mean-Square Error (RMSE) is a frequently used measure of the differences between the original and reconstructed images and defined as, $RMSE = \sqrt{MSE}$.

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|f_i - y_i| = \frac{1}{n}\sum_{i=1}^{n}|e_i|\,.$$

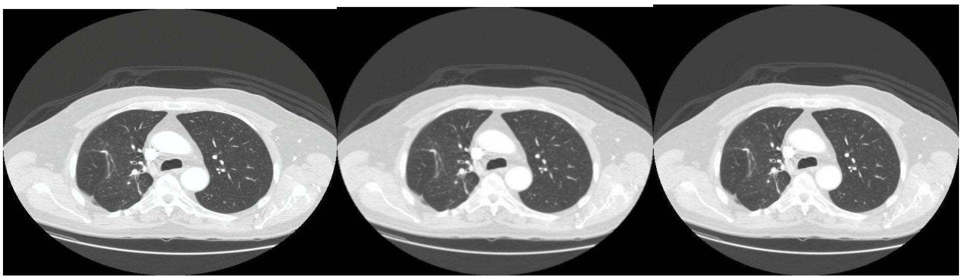
Mean Absolute Error (MAE) is used to measure how the reconstructed image close to the original image and the value is defined as,

The higher PSNR value, lower MSE value, lower RMSE value and the lower MAE indicates the better noise removal.

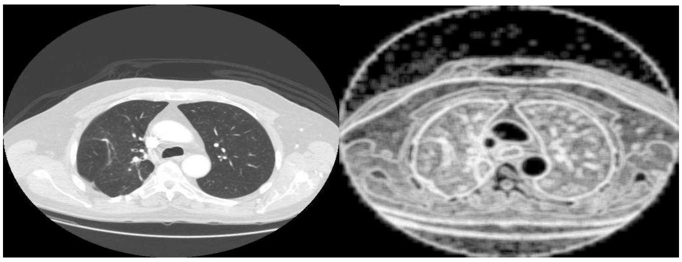
RESULTS AND DISCUSSIONS

In our experiment we uses LIDC-IDRI CT scan images. The Lung Image Database Consortium image collection

(LIDC-IDRI) consists of diagnostic and lung cancer screening thoracic CT scans with marked-up annotated lesions. It is a web-accessible international resource for development, training, and evaluation of computer-assisted diagnostic (CAD) methods for lung cancer detection and diagnosis. Each study in the dataset Consist of collection of slices and each slice of the size of 512 X 512 in DICOM format. The lungs image data, nodule size list and annotated XML file documentations can be downloaded from the National Cancer Institute website [7]. For the experiment we taken 75 Non-Cancer Lung CT scan images and 180 Cancer Lung CT images from the LIDC dataset.

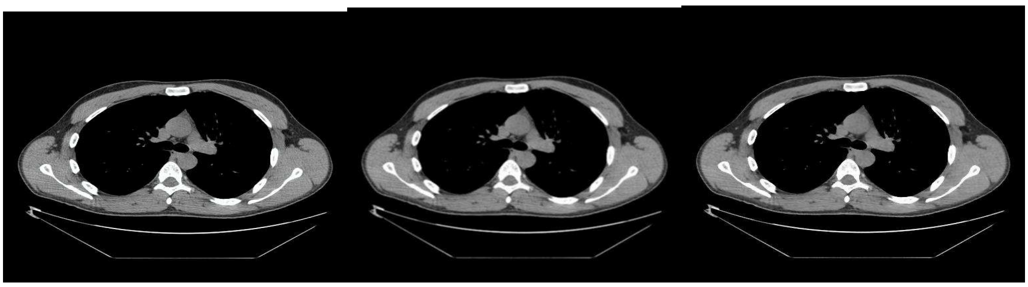


(a) (b) (c)

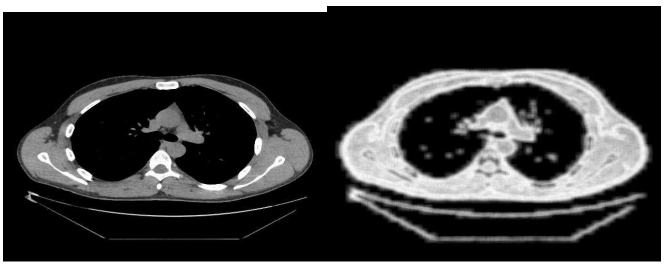


(d) (e)

Figure 1: Different Linear and Non-Linear Filters Applied for Lung CT Scan Cancer Image: (a) Original Image (b) Mean Filter Applied (c) Wiener Filter Applied (d) Median Filter Applied and (e) Entropy Filter Applied Image



(a) (b) (c)



(d) (e)

Figure 2: Different Linear and Non-Linear Filters Applied for Lung CT Scan Non-Cancer Image: (a) Original Image (b) Mean Filter Applied (c) Wiener Filter Applied (d) Median Filter Applied and (e) Entropy Filter Applied Image

Table 1: Image Quality Measures for Both the Linear and Non-Linear Filters for Lung CT Scan Images

Image Quality Measures		Lung Cancer Filtered Images (Average Value of 180 Images)				Lung Non-Cancer Filtered Images (Average Value of 75 Images)			
		MSE	RMSE	PSNR	MAE	MSE	RMSE	PSNR	MAE
Linear Filters	Mean	159.27	12.326	07.246	86.364	146.34	11.787	07.635	79.896
	Wiener	06.24	02.216	38.799	00.892	18.91	03.870	32.837	02.406
Non-linear Filters	Median	07.95	02.579	35.910	01.081	21.45	04.204	28.512	03.992
	Entropy	158.34	12.276	07.432	84.156	144.94	11.716	07.848	77.555

From table 1, the frequency domain based linear filter called wiener filter performs very well in all type of lung CT scan images where compare with the other linear and non-linear filters. The median filter also performs well compare with mean and entropy filter. The wiener filter reduces the Gaussian noise and random noise in very good manner without losing the image information.

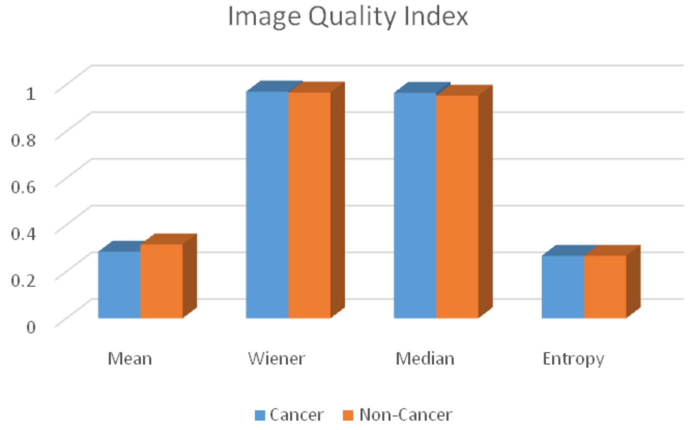


Figure 3: Image Quality Index for Both the Linear and Non-Linear Filters

From figure 3, the image quality index also high for the wiener filter compare with the median filter for both cancer and non-cancer images. The mean and entropy filters not reducing as much of noise in both the cases.

CONCLUSIONS

In this paper, we compared the image filtering methods for lung CT scan images and obtained results for filters namely mean filter, wiener filter, median filter and entropy filter. By investigating the comparison parameters, it is clear that wiener filter performs very well compare with the other filtering methods. The wiener filter provides the maximum PSNR, Image quality index value and minimum MSE, RMSE, and MAE. The wiener filter reduces noises in lung CT scan images for both the cancer and non-cancer images.

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